INVESTIGATION OF THE DENSITY DISTRIBUTION IN THE

DETONATION FRONT OF GAS MIXTURES BY THE

X-RAY EXAMINATION METHOD

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It was predicted that substances in a detonation wave would first be subjected to impact compression and only afterward burn up. At each instant, a layer of compressed air would form in the detonation wave between the undisturbed gas mixture in its initial state and the combustion products in a state determined by the thermodynamic theory.

The thickness of this layer is proportionate to the time required for the liberation of heat in the chemical process of reaction of compressed gas.

In spite of the fact that more than 15 years have passed since this relation was clearly formulated (1-3), experimental data on a compressed layer in a detonation wave front remain very scanty (4-6).

The attempt of Kistyakov and his collaborator (7,8) to study this layer with the aid of an X-ray densitometer, making use of a scintillation counter and oscillographic techniques, did not yield any well-defined results due to the inadequacy of the method. The further development of this technique was basically directed towards increasing the accuracy of measurement of gas density (9).

In 1945, M. A. Rivin, Ya. B. Zel'dovich, and V.A. Tsukerman proceeded with the investigation of the density in the detonation front of detonating gas mixtures with hydrogen iodine by the X-ray pulse examination method. Due to M. A. Rivin's illness and death, however, these investigations were discontinued.

The experiments were resumed in 1957. A peculiarity of the method applied in the present work is the application of a pulse needle tube (10) with a zirconium anode as an X-ray radiation source, and krypton as an absorbing addition

*deceased.

to the detonation gas. The characteristic radiation of zirconium ($\lambda_{K_\alpha}=0.788Å$) falls into the absorption band of krypton. The above-indicated combination of radiation and absorbing admixture rendered possible the measuring of density in relatively thin layers of gas mixtures.

In the basic series of tests regarding the investigation of the detonation of detonating gas mixtures with krypton, organic glass tubes of a 20-millimeter inside diameter and 1.5-millimeter wall thickness were used. The initial gas pressure amounted to 0.5 kilograms per square centimeter. Control tests on the X-ray impact wave in pure krypton were carried out in tubes of five-millimeter I.D. and at an initial pressure of one kilogram per square centimeter.

The initiation of a detonation in a gas mixture and an impact wave in pure krupton was carried out by the electrical "fusion" of a nichrome wire, 0.1 millimeter in diameter, at the discharge of a low-inductance 20-microfarad capacitor, charged to a voltage of five to six kilovolts.

Simultaneously with the X-ray examination of the wave, the detonation speed was measured with the aid of an electron-beam oscillograph.

The blurred images in the direction of the detonation, at an X-ray flare of a 0.2-second duration, extended for not more than three millimeters. The deflection of the X-rays from the front plane was controled and in the majority of cases did not exceed one degree. The additional blurring connected with the final dimensions of the focal spot (1.5 mm), in the assumed geometry of the exposure, did not exceed 0.1 millimeter. The total blurring of the image by the described method can be estimated at 0.4 to 0.5 millimeter.

The basic result of the work is the definite observation in the front of the detonation wave of a narrow gas layer, whose density exceeds the initial density by three or four times (the so-called chemical peak region); in most tests, its width (by taking into consideration corrections due to blurring) amounts to 0.1 to 0.3 millimeter and lodges on the boundary of the applied method.

The curves of density distribution in an impact wave in pure krypton and in a detonation wave of detonating gas mixture with krypton, obtained by the microphotometric processing of pulse X-ray pictures, are presented in Figure 1.

The region in which the density in the front of the detonation wave is considerably higher than the calculated density of the products of the reaction is made very apparent.
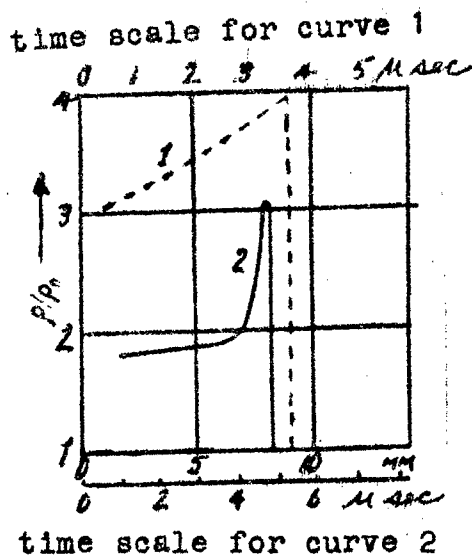
time scale for curve 1

time scale for curve 2

Fig. 1. Distribution of relative gas density ρ/ρ_0.

1. Impact wave in pure krypton at a distance from the initiating point to the front of 42 mm and speed of 2.4 km/sec;
2. Detonating wave in a 20% H_2 + 10% O_2 + 70% Kr mixture at a distance from the initiating point to the front of 400 mm and detonation speed of 1.3 km/sec.

The experimental value of $\rho/\rho_0 \approx 3$ obtained in this experiment is apparently reduced, due to the fact that the width of the chemical peak region approaches the threshold space permissibility of the method.

In spite of the large number of conducted tests, no specific relationship of the peak width to the composition and pressure of the mixture has yet been successfully established. Further investigations will require an improved space and time solution of the method. It is also possible that the selection of another detonation mixture will permit the widening of the high-density region in the front of the detonating wave and the obtainment of more accurate qualitative relations with the present measuring techniques.

We take advantage of this occasion to express our profound gratitude to N. N. Orlova, who participated in the above experiments, Ye. I. Leont'ev, who conducted the tests in 1945, and to R. M. Zaydel for his assistance in the calculations and for valuable discussions.

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